

Eastham Freshwater Ponds: Water Quality Status and Recommendations for Future Activities

FINAL REPORT

April 2009

for the



Town of Eastham
and
Barnstable County



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Cover photo: samplers on Muddy Pond (Tony Mancini, August 2008)

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Executive Summary

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Cape Cod ponds are part of the regional aquifer system and, as such, are linked to drinking water and coastal estuaries, as well as any pollutants added to the aquifer. In Eastham, water quality in the ponds are generally a reflection of the amount of development around the ponds, including impacts from wastewater, fertilizers, and stormwater runoff, as well as the individual characteristics of each pond. Until the Cape Cod Pond and Lake Stewardship (PALS) program was created, water quality in most ponds was limited to anecdotal information from long time residents.

The Cape Cod PALS program provides a focus for local pond concerns and staff from Coastal Systems Program at the School of Marine Science and Technology (SMAST), University of Massachusetts Dartmouth and the Cape Cod Commission (CCC) provide training and guidance to local volunteers about collecting water quality samples, as well as discussing pond water quality and use management. Volunteer water quality sampling activities have led to eight consecutive, annual PALS water quality snapshots, which have included free laboratory analysis through SMAST for any collected pond water quality samples, and citizen enthusiasm has led to more grant-supported, citizen monitoring with laboratory services provided through the Cape Cod National Seashore. All these monitoring activities have created a large dataset of volunteer-collected pond water quality data in need of analysis and interpretation.

Through funding provided by Barnstable County, SMAST staff have been contracted by the CCC to review the available laboratory and field water quality data collected by Town of Eastham volunteers from 10 ponds between 2001 and 2006. This review also includes a detailed review of six ponds selected by the Town of Eastham Water Resources Advisory Board: Great, Herring, Muddy, Depot, Minister, and Schoolhouse. These detailed, pond-specific reviews include delineation of pond watersheds, development of water and phosphorus budgets, characterization of the ponds ecological status, and recommendations for next steps.

Regulations, Management Strategies and Nutrient Thresholds

Assessing the condition of a pond ecosystem is generally about both assessing the ecological conditions and comparing those conditions to regulatory thresholds. Regulatory standards are defined as an interpretation of a federal, state, or local law, while ecological gauges are generally based on comparisons to similar ponds in similar settings or to historic information about the pond under review. Since regulatory standards have the power of law, community action can be compelled by regulatory entities, while meeting ecological gauges are usually based on the local value of the resource. Effective management strategies address both ecological and regulatory goals.

State Regulatory Standards, Clean Water Act and TMDLs

All freshwater ponds in Massachusetts that are not drinking water supply sources are classified as “Class B” waters under Massachusetts Surface Water Quality Standards regulations (314 CMR 4). According to these regulations, Class B waters must have “consistently good aesthetic value” and have the following designated uses: “habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation” [314 CMR 4.05(3)(b)]. These regulations have been written to interpret the Massachusetts Clean Water Act (Massachusetts General Law c. 21, §§ 26 through 53) and the Massachusetts’ role in implementing the federal Clean Water Act. The Massachusetts Department of Environmental Protection is the regulatory agency responsible for implementation of both the state and federal Clean Water Acts.

Massachusetts Surface Water regulations have a concentration limit for dissolved oxygen, which is one of three numeric ecological water quality standards for freshwaters in the regulations; temperature and pH are the other two. According to the regulations, dissolved oxygen concentrations “shall not be less than 6.0 mg/l in cold water fisheries and not less than 5.0 mg/l in warm water fisheries” [314 CMR 4.05(3)(b)1.]. All the numeric regulatory standards have provisions to allow “natural” readings outside of the specified ranges; for example, pH readings in most Cape Cod ponds are lower than the state 6.5 limit, but a strong case is available that most ponds in the southeastern Massachusetts outwash plains (like Cape Cod, Plymouth, and portions of Wareham) have natural pH readings less than 6.5 (Eichner and others, 2003).

Any waters failing to meet the numeric standards in the state Surface Water regulations are defined as “impaired” for the purposes of federal Clean Water Act compliance and all impaired waters are required by the Act to have a Total Maximum Daily Load (TMDL) established for the contaminant that is creating the impairment. Under the Clean Water Act, states are required to create implementation plans to meet TMDLs; DEP guidance to date has focused on having community-based comprehensive wastewater plans include provisions to meet TMDLs.

Other than the limited numeric standards, the other state compliance threshold is whether a pond is supporting all designated uses. The pertinent portion of the regulations states that: “Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses...Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control” [314 CMR 4.05(5)(b)3.]. Given that this is an interpretive threshold, it is often a pathway to begin to discuss ecological conditions.

Nutrient Limits for Eastham Ponds

In an effort to address the high number of impaired waters around the United States, the federal Environmental Protection Agency (EPA) has proposed a procedure to develop “nutrient criteria” for various water resources, including lakes and ponds (EPA, 2000). This method relies on gathering data throughout an area or “ecoregion” with similar assemblages of natural communities and species and using that data to determine what are reasonable criteria or limits to

protect the ponds in this area from impairments. At this point, EPA's method is used to produce numeric guidelines, not regulatory standards.

All of Cape Cod is within EPA's Atlantic Coastal Pine Barrens Ecoregion (Griffith and others, 1999). As a result of the Cape Cod PALS water quality snapshot in 2001, volunteers collected nutrient samples from 195 ponds. Using this data, the CCC applied the EPA nutrient criteria procedures and determined nutrient criteria for total phosphorus, total nitrogen, and chlorophyll *a* (Eichner and others, 2003).

The EPA nutrient criteria guidance defines two approaches to determining nutrient criteria: one based on so-called "reference" or relatively pristine ponds and another based on all available pond data regardless of water quality conditions. The respective standards based on the surface water samples from the 2001 Cape Cod dataset are: chlorophyll *a*, 1.0 and 1.7 ppb; total nitrogen, 0.16 and 0.31 ppm; and total phosphorus, 7.5 and 10 ppb (Eichner and others, 2003).

Town-wide Pond Water Quality

Review of the volunteer data from 10 Eastham ponds monitored between 2001 and 2006 indicates that eight of the ponds have average dissolved oxygen concentrations that fail to attain minimum thresholds in the state surface water regulations. Jemima and Muddy are the two ponds that meet state dissolved oxygen standards. Review of average nitrogen and phosphorus concentrations finds that all ponds are phosphorus limited, which means that management of phosphorus will be the key for determining water quality in these ponds and reductions in phosphorus will have to be part of remediation plans. Review of average total phosphorus concentrations also shows that all of the ponds exceed the 10 ppb "healthy" threshold that was developed specifically for Cape Cod ponds (Eichner and others, 2003).

Detailed Pond Water Quality Assessments

Six ponds were selected by the Town for more detailed review by SMAST staff: Great, Herring, Muddy, Depot, Minister, and Schoolhouse. These detailed reviews allow the review of water quality data completed in the town-wide overview to be enhanced and brought into a better context and understanding of how watershed and in-lake factors influence the water quality that is measured. These detailed reviews incorporate watershed information, development of water budgets to determine how water moves in and out of each pond, and development of phosphorus budgets to help understand the likely sources of the nutrient for each individual pond. The phosphorus budget development includes review of surrounding land uses, which also allows project staff to develop estimates of both existing and future sources of phosphorus loads and better understand any phosphorus travel delays in the aquifer.

Because phosphorus moves very slowly in Cape Cod aquifer conditions, it can take decades for some loads from even nearshore sources, such as septic systems, to reach a pond shoreline and discharge into the pond. Comparison of existing conditions to projected future loads in the six ponds show that only a fraction of the steady-state watershed nutrient loads have reached the ponds; water quality will worsen as more of the phosphorus already in the aquifer reaches pond and the systems move closer to steady state.

The detailed review of the six individual ponds also shows that all but Muddy have both ecological and regulatory impairments. Development of appropriate and cost-effective water quality restoration strategies for all these ponds will require collection of some additional information to develop adequate understanding of phosphorus sources. All ponds require sampling of their sediments to directly measure current and future potential sediment phosphorus loading. Review of the phosphorus budgets also indicates that development of pond-specific information about stormwater inputs and aquatic bird populations is important for effectively targeting restoration strategies. Collection of this information, along with other recommended pond-specific data, will refine the phosphorus budgets and ensure that management and restoration strategies accurately target the sources of the impairments in these ponds.

Brief individual descriptions of the status of each of the ponds selected for more detailed review follow:

Great Pond

Great Pond is a 110-acre pond that is located to the west of Route 6. Its deepest point is 13 m (~43 ft), which is the deepest Eastham pond selected from detailed review. Water quality in Great was reviewed once before as part of a diagnostic/feasibility study (BEC, 1987). Temperature stratification during the summer in Great means the pond meets the state regulatory requirements to be classified as a cold water fishery (314 CMR 4). Average dissolved oxygen concentrations in this lower layer fail to meet state regulatory minimum and, as such, this pond would be classified as impaired under state regulations and would be required to have a TMDL (Total Maximum Daily Load) developed.

The state Department of Environmental Protection already acknowledges that a TMDL is required for Great Pond. DEP is required to submit a list of impaired waters to EPA every two years in fulfillment of reporting requirements of sections 305(b) and 303(d) of the Clean Water Act. Great Pond is listed as needing a TMDL for “nutrients” and “organic enrichment/low DO” (www.mass.gov/dep/water/resources/2006il4.pdf).

In order to develop a TMDL and associated strategies to meet it, additional information about the sources of nutrients and their impact on the water quality in Great Pond is necessary. It is recommended that town consider targeted data collection to develop the necessary information and resolve the management uncertainties. Key data to collect include sediment core analysis and a pond-specific evaluation of year-round bird populations. It is further recommended that this data be paired with coincident water quality data in the pond and the stream outflow to Bridge Pond. Collection of all this information at the same time will allow create more confidence in the characterization of the system and whatever management strategies that are developed.

This study would build on the results in this current report and answer the questions that have been raised, but left unanswered, by the currently available data. SMAST staff recommend that this study include the following at a minimum: 1) collection and incubation of three sediment sample cores to determine phosphorus content, regeneration potential, and dissolved oxygen thresholds, 2) a whole year of observation of bird populations on the pond, including identification of species, 3) at least monthly measurement of stream outflow and analysis of

accompanying water quality samples, and 4) at least monthly collection of water quality samples in the pond using the standard PALS procedures including dissolved oxygen and temperature profiles and standard laboratory analysis plus other chemical constituents that might influence phosphorus regeneration. Development of this information could then be used to develop recommendations and costs for management strategies. SMAST staff have estimated that the cost of a stand alone project with these recommended activities at between \$25,000 and \$30,000 with another \$11,000 to \$13,000 for combining this information with past information and developing water quality management strategies and a recommended TMDL. Additional analysis that should be considered and would help to clarify interactions in the pond and potential management activities would include a survey of rooted plants, phytoplankton and epiphytic algae, an updated bathymetric map, a survey and map of sediment thickness, and evaluation of stormwater structures around the pond. Potential savings might be realized by completing this type of targeted analysis on a number of ponds and/or by incorporating citizen volunteer participation where appropriate.

Herring Pond

Herring Pond is a 44-acre, 35 ft (10.7 m) deep pond that is located to the south of Great Pond and west of Route 6. Water quality in Herring was previously reviewed as part of a diagnostic/feasibility study (BEC, 1991). Herring thermally stratifies usually in late May/early June starting with a warm upper layer of 3 to 4 m in June and deepening to 5 or 6 m by September. Once stratification sets up, oxygen consumption from the sediments regularly creates anoxic (<1 ppm) conditions in the deepest portions of the pond with concentrations generally less than state standards in waters 8 m and below. Summer temperatures deeper than 6 m meet the temperature criterion (less than 20°C) in the state surface water regulations (314 CMR 4) to be classified as a cold-water fishery.

Review of average dissolved oxygen conditions show that waters 8 m and deeper are less than the state 6 ppm dissolved oxygen standard the majority of the time between June and September and that anoxic conditions can rise as shallow as 6 m. Comparisons of the dissolved oxygen and temperature readings means that average summer conditions have approximately 1 meter (between 7 and 8 meters in depth) worth of acceptable cold water fishery in Herring Pond. The regular lack of sufficient oxygen and occasional anoxic conditions suggests that Herring's cold water fishery is not sustainable and reinforces the classification of Herring as impaired under state surface water regulations and, thus, in need of a TMDL.

Herring Pond is listed on the DEP integrated waters list as a Category 3 water, which means that it is in the "no uses assessed" category. This means that in DEP's required reporting to EPA that Herring Pond is recognized as a water of the Commonwealth, but no water quality assessment has been completed to determine whether a TMDL is required or not.

Secchi readings suggest that the pond ecosystem is highly unstable, which would be consistent with a pond that has a significant internal source of phosphorus readily available from the sediments. Water column measurements show that the mass of phosphorus in the pond doubles during some summers, which strongly suggests an internal sediment source, but available data is insufficient to completely rule out additional phosphorus beginning to reach the pond from its watershed. Direct measurement of sediment regeneration through the collection

and incubation of at least three cores is the lowest cost option to resolve this issue and will provide a better basis to move forward with management strategies.

In addition to sampling the sediments, targeted measurements of other factors is recommended to lay the groundwork for a TMDL and effective management strategies. These recommended measurements include: 1) evaluation of the plant community to gauge whether there have been significant changes since the BEC (1991) study and whether loss of rooted plants might also be a cause of increasing phosphorus loads, 2) direct evaluation and measurement of stormwater phosphorus inputs to accurately gauge this source, and 3) concurrent stream gauging and water quality measurement with at least monthly measurements to assess phosphorus outflows. Stream gauging should also note salinity readings. This targeted study should also be complemented by a year-long bird counting and identification study, which could be developed as a volunteer activity and coincident at least monthly water quality samples. It is recommended that all these measurements occur with the same time period so that a comprehensive dataset is generated to be used in management assessments. SMAST staff have estimated that the cost of a stand alone project for these recommended activities between \$32,000 and \$35,000 with another \$11,000 to \$13,000 for combining this information with past information and developing water quality management strategies and a recommended TMDL. Additional analysis that should also be considered would be an updated bathymetric map, a survey and map of sediment thickness, and an evaluation of stormwater structures around the pond. Potential savings might be realized by completing this type of targeted analysis on a number of ponds and/or by incorporating citizen volunteer participation where appropriate.

Muddy Pond

Muddy Pond is a 10.5-acre, 1.6 meter (5.2 feet) deep pond located to the east of Herring Pond and west of Route 6. It is the shallowest of the ponds selected from detailed review and, as such, generally has consistent water column temperatures from surface to bottom; average temperatures between June and September are 24.2°C at 0.5 m (n=25) and 24.1°C at 1 m (n=22). Given its temperatures and shallow depth, Muddy Pond would be classified as a warm-water fishery by the state. State surface water regulations (314 CMR 4) generally define warm-water fisheries as having maximum mean monthly summer temperature exceeding 68°F (20°C).

Muddy Pond is not listed in the Massachusetts integrated waters list that DEP is required to submit to EPA every two years in fulfillment of reporting requirements the Clean Water Act. Since its area is larger than the state 10 acre “Great Pond” threshold, Muddy Pond is technically a water of the Commonwealth, but its lack of mention in the integrated list is a reflection of the incompleteness of the integrated list.

Although Muddy Pond is not on the integrated list, it meets the state dissolved oxygen standard for the best water quality. Warm water fisheries are required under state surface water regulations to have dissolved oxygen concentrations of at least 5 parts per million (ppm). Average dissolved oxygen concentrations in Muddy Pond between June through September are 7.5 ppm at both the 0.5 and 1 m depth stations. Only one of 20 readings at the deepest station was below the state 5 ppm standard.

Although Muddy Pond meets the state dissolved oxygen standards, it does have relatively high phosphorus concentrations. Average total phosphorus (TP) concentrations in Muddy Pond between June and September are greater than both pertinent Cape Cod-specific thresholds: 22.9 ppb at 0.5 m (n=15) and 27.5 ppb at 1 m (n=12). The phosphorus budget suggests that there will be a slight rise in average concentrations over the next ten years, but these concentrations are close to steady-state conditions. In contrast to this assessment, however, is an increasing trend in the measured mass of phosphorus in the pond. This suggests that there is more mass entering the water column every year; whether this is a watershed or an in-lake, internal source is not clear.

Given that Muddy Pond is relatively shallow, it is unlikely that it will ever fail to meet dissolved oxygen limits in the state regulations. Available wind energy across the pond surface will supply a constant source of oxygen, even if sediment oxygen deficits occur. Since dissolved oxygen concentrations are the primary numeric state water quality standard, it is unlikely that the town would be required to address water quality management by state regulators unless excessive algal blooms occur or other ecosystem/aesthetics arise.

The biggest concerns for future management of aesthetics and ecosystem function are the existing high phosphorus concentrations and the increasing mass of phosphorus in the pond. Given the readily available supply of phosphorus, the potential for spontaneous algal blooms and accompanying decreases in clarity is relatively high. Gaining a better understanding of the sediments will allow the town to effectively manage the primary source of phosphorus: either the watershed or the sediments. In to develop a better understanding of the sediments, it is recommended that the town consider collection of sediment cores and testing of the cores to gauge the maximum amount of expected phosphorus release from the sediments and the dissolved oxygen conditions that would cause this release to occur. SMAST staff have estimated that a stand alone project for the cost of the collection, analysis, interpretation of this sediment data and updating management strategies at between \$8,000 and \$10,000.

In addition, observation of other Cape Cod ponds with high phosphorus concentrations suggests that these ponds may be more susceptible to shifting from a phytoplankton-dominant plant community to one dominated by rooted plants. In the later case, Secchi clarity will initially improve, but over the longer term, the surface of the pond may slowly be covered by plants and recreational options will become more limited. With this in mind, it is also recommended that the town consider completing a current baseline evaluation of rooted plants in Muddy Pond. This evaluation should include identification of species and percentage of plant coverage throughout the pond. SMAST staff have estimated that a stand alone project for the cost of the collection, analysis, interpretation of this plant data at between \$8,000 and \$10,000. Potential savings might be realized by completing these recommended analyses on a number of ponds and/or by incorporating citizen volunteer participation where appropriate.

Depot (Long) Pond

Depot Pond is a 27.9-acre, 10 meter (~33 feet) deep pond that is located to the east of Great Pond, west of Route 6, and to the north of Muddy Pond. Depot is referred to on some historic and current maps as Long Pond. Depot stratifies into thermal layers with a well mixed upper layer that deepens from 2 m to 4 or 5 m throughout the summer. The deeper waters have decreasing temperature with depth, which indicates that these waters are not well mixed.

Average summer temperatures at 6 m and deeper meet the state 20°C cold-water fishery regulatory standard.

Dissolved oxygen data shows that there is on-going oxygen consumption throughout the summer. Once the thermal layers are established and the lower layer is cut off from oxygen replenishment from the upper waters, oxygen consumption from the sediments creates regular anoxic (<1 ppm) conditions in the deepest portions of the pond. Anoxic conditions have been measured as shallow as 7 m from the surface. The state regulatory standard of 6 ppm DO is usually met down to a depth of 5 m. Overall, all of the available cold water fishery and 21% of the total pond volume fail to meet state dissolved oxygen limits. Based on state surface water regulations, Depot Pond would be classified as having impaired water quality and, as such, would eventually be required to have a TMDL.

Depot Pond is listed on the DEP integrated waters list as a Category 3 water, which means that it is in the “no uses assessed” category. This means that in DEP’s required reporting to EPA that Depot Pond is recognized as a water of the Commonwealth, but no water quality assessment has been completed to determine whether a TMDL is required or not.

Although the dissolved oxygen readings clearly show that Depot Pond is impaired, average total phosphorus (TP) concentrations are only slightly above the Cape Cod 10 ppb “healthy” threshold. In order to try to reconcile this, project staff reviewed the individual sampling runs and compared TP and DO concentrations and found a high number of apparently inconsistent results (e.g., low DO with low TP). Review of DO concentrations found that they were highly consistent throughout the dataset, while TP concentrations are inconsistent. This inconsistency between the two dataset should be resolved prior to the development of definitive management strategies for Depot Pond.

It is recommended that the town consider a targeted one year analysis of Depot Pond with a focus on components of the phosphorus budget, resolving the inconsistencies in the various datasets, and laying the groundwork for preparation of a TMDL. This analysis will allow the town to develop management strategies that can be confidently pursued. SMAST staff recommend that this study include the following at a minimum: 1) collection and incubation of three sediment sample cores to determine phosphorus content and regeneration potential related to dissolved oxygen thresholds, 2) a plant survey, 3) a whole year of observation of bird populations on the pond, including identification of species, and 4) at least monthly collection of water quality samples in the pond using the standard PALS procedures including dissolved oxygen and temperature profiles and standard laboratory analysis plus other chemical constituents that might influence phosphorus regeneration. It is recommended that all these measurements occur with the same time period so that a comprehensive dataset is generated to be used in management assessments.

Development of this information could then be used to develop recommendations and costs for management strategies. SMAST staff have estimated that the cost of a stand alone project for these recommended activities between \$32,000 and \$35,000 with another \$11,000 to \$13,000 for combining this information with past information and developing water quality management strategies and a recommended TMDL. Additional analysis that should be

considered and would help to clarify interactions in the pond and potential management activities would include an evaluation of stormwater structures around the pond. Potential savings might be realized by completing these recommended analyses on a number of ponds and/or by incorporating citizen volunteer participation where appropriate.

Minister/Schoolhouse Pond

Minister Pond is a 22.3 acre pond located to the east of Route 6 and to the north of Salt Pond. Minister Pond has two basins: the northernmost 16.8 acre, 4.3 meters (14.1 feet) deep basin which is usually called Minister Pond and a 5.6 acre, 4.5 meters (14.9 feet) deep southern basin that is usually called Schoolhouse Pond. Minister and Schoolhouse essentially share the same watershed, although Minister receives the bulk of the watershed-derived groundwater discharge and likely discharges most of this flow to Schoolhouse via their hydroconnection over a submerged isthmus.

The water column in both Minister and Schoolhouse does thermally stratify into layers; both have very thin (1-1.5 m) layers of warm and cold water at the top and bottom separated by transitional zone. Given their relatively shallow depth, this is somewhat exceptional; a similar temperature regime was measured in Boland Pond, which is a shallow pond in Orleans (Eichner, 2007).

Both Minister and Schoolhouse appear to have extensive internal sediment oxygen demand. Summer surface dissolved oxygen concentrations average 6.5 ppm, which is 74% saturation; most ponds on Cape Cod typically have 90-100% saturation in their upper waters. Both ponds have had surface water dissolved oxygen concentrations below 5 ppm, the lowest state surface water regulatory standard. Average summer DO concentrations in the bottom waters are anoxic (<1 ppm); maximum concentrations at these depths during the summer do not attain 5 ppm. Anoxic conditions rise as high as 2 m below the surface in both ponds. Based on state surface water regulations and these average dissolved oxygen readings, Minister and Schoolhouse, either combined or separately, would be classified as having impaired water quality and, as such, would eventually be required to have a TMDL.

Neither Minister nor Schoolhouse are listed in the Massachusetts integrated waters list that DEP is required to submit to EPA every two years in fulfillment of reporting requirements the Clean Water Act. Since its combined area (or Minister by itself) is larger than the state 10 acre “Great Pond” threshold, Minister Pond is technically a water of the Commonwealth, but its lack of mention in the integrated list is a reflection of the incompleteness of the integrated list.

Average total phosphorus (TP) concentrations between June and September in both Schoolhouse and Minister are more than double the Cape Cod 10 ppb “healthy” threshold. The total mass of phosphorus in each pond is consistent with Minister acting as an initial “cleansing” basin and the recipient of most of the loads from the watershed.

Although the TP concentrations in the two basins are high, project staff expected that there would be a higher average concentrations in the deeper stations. In order to try to reconcile this, individual sampling runs were reviewed to compare TP and DO concentrations. This review found a high number of apparently inconsistent results (*e.g.*, low DO with low TP),

primarily focused in the 2003 sampling season. Review of DO concentrations found that they were highly consistent throughout the dataset, while TP concentrations are inconsistent and that concentration results in the shallow and deep samples appear to be reversed. Switching these concentrations results in consistency between the DO and TP results. Although the TP concentrations need to be resolved in order to develop reliable management strategies, the DO readings clearly show that these ponds are impaired and that remediation will have to be undertaken.

It is recommended that the town consider a targeted one year analysis of Minister/Schoolhouse Pond with a focus on components of the phosphorus budget, resolving the inconsistencies in the various datasets, and laying the groundwork for preparation of a TMDL. This analysis will allow the town to develop management strategies that can be confidently pursued. SMAST staff recommend that this analysis include the following at a minimum: 1) collection and incubation of three sediment sample cores in each basin to characterize the amount of available phosphorus and the dissolved oxygen conditions that prompt its release, 2) concurrent monthly water quality sampling in each basin between April and November, 3) characterization of the internal movement of water and nutrients between Minister and Schoolhouse, 4) identification of stormwater structures and measurement of any stormwater inputs into Minister and Schoolhouse, and 5) identification and counts of birds on the two ponds throughout a year. It is recommended that all these measurements occur with the same time period so that a comprehensive dataset is generated to be used in management assessments.

Development of this information could then be used to develop recommendations and costs for management strategies. SMAST staff have estimated that the cost of a stand alone project for these recommended activities between \$35,000 and \$40,000 with another \$11,000 to \$13,000 for combining this information with past information and developing water quality management strategies. Potential savings might be realized by completing these recommended analyses on a number of ponds and/or by incorporating citizen volunteer participation where appropriate.

Conclusions and Town-wide Recommendations

Five of the six ponds selected for detailed review have impaired water quality based on state surface water regulations thresholds and will require TMDLs. Review of dissolved oxygen concentrations in the town-wide dataset show that there are three additional ponds that may also be impaired, although more refined analysis is recommended. Review of nutrient concentrations show that all the ponds that have been monitored have excessive nutrients. Although it is clear that pond water quality will have to be more of a focus in the future, what is not clear is how management activities should be targeted in a cost-effective way to address these issues in each pond.

In order to organize all of these needs, it is recommended that the Town of Eastham consider development of a pond remediation program. This program would be tasked with completing watershed loading, water and nutrient budget development and water quality review for the three remaining ponds with adequate data that were not selected for detailed review and . working on the implementation of the recommendations discussed above for the six ponds that have detailed reviews in this report. This program would also be the central focus for

development of the required funding for remedial in-lake activities, such as alum treatments and aeration, which are likely to be necessary for many of these ponds in the future, as well as implementation of best management practices, such as removing or minimizing stormwater discharge into the ponds. The town could also consider expanding this program to deal with other management issues such as watershed planning, fish stocking issues, and on-going questions of access. It is also recommended that this program be integrated with the on-going pond monitoring program; this program has been the key in developing the available information and will continue to be a key in providing community feedback on proposed remedial strategies, as well as measuring the results of remedial efforts. Town of Eastham and SMAST staff could discuss opportunities to jointly manage a pond remediation program.

Included under the umbrella of this program, it is also recommended that the town begin the implementation of best management practices for shoreline properties. Given that all the ponds have excessive phosphorus concentrations and any in-lake remedial steps will have to also include watershed reductions in order to sustain them, these steps are recommended throughout the town. These practices can slowly reduce the mass of phosphorus entering the ponds and are all relatively inexpensive to implement. As mentioned previously, these practices include: 1) maintaining, planting, or allowing regrowth of natural buffer areas between the pond and lawns/yards/houses, 2) installing treatment for or redirecting any direct stormwater runoff, and 3) ensuring that all new septic system leachfields have an adequate setback from the pond (at least 300 feet or the maximum possible on a lot).

These best management practices could be implemented through both changes in town regulations and local educational efforts. Review of existing town regulations (*i.e.*, subdivision rules, conservation commission regulations, board of health regulations) for opportunities to better protect pond water quality could be a first step. Implementation of any changes could occur when properties change ownership. The town may also want to consider combining all of these activities with monitoring programs, so all pond-related activities are coordinated and mutually supportive.

It is clear from this review and the individual pond assessments that addressing all of these issues will require resources and sustained commitment. SMAST, as part of the University of Massachusetts Dartmouth, has a commitment to the communities of southeastern Massachusetts and staff would be available to assist the town in realizing the restoration and protection of Eastham's pond resources.

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